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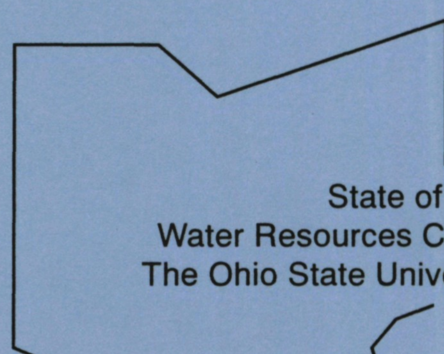
Report No. G-2039-06

FISCAL YEAR 1995 PROGRAM REPORT

Earl Whitlatch
Director

United States
Geological Survey



State of Ohio
Water Resources Center
The Ohio State University

FISCAL YEAR 1995 PROGRAM REPORT

Ohio Water Resources Center
The Ohio State University
Ohio

Report No.
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Grant No. 14-08-0001-G 2039-06

for

U. S. Department of the Interior
Geological Survey

by

Ohio Water Resources Center
The Ohio State University
Columbus, OH 43210-1057

Earl Whitlatch, Director

September, 1996

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ABSTRACT

Most of Ohio's water problems are associated with water quality. Of primary concern are the sediments, nutrients and acids in the surface waters from urban, agricultural and mining areas, and the toxic and hazardous wastes that threaten the ground and surface waters. The focus of the 1995 State Water Research Program was directed at these areas. The research and technology transfer program consisted of the following activities: The technology transfer programs continue to disseminate information about water resources in Ohio to the local and state decision-makers. Professional training and development was also provided to 1,000 water resources managers throughout the year. In addition, there was 1,768 teachers trained to teach water resources activities and they in turn provided training to 44,200 Ohio students. The program also provided technical assistance to help resolve some of the state's major water problems. One project was a fate and transport study of herbicides through a watershed and to a lake which provided most of the drinking water for the community with water quality throughout the watershed was done. Another project studied the effect on invertebrates to various levels of dioxions in the water and sediments. These studies will eventually lead to a better understanding of the risks dioxins have on humans. The third research project studied the design for a bioreactor that would efficient and efectively clean gasoline components from water through bioremediation.

Training on these research projects was provided to five students from three colleges in three disciplines at two universities. These include one M. S. Student in Geology and 4 Ph. D. Students in the fields of Biological Sciences - Environmental Toxicology, and in Food, Agriculture and Environmental Sciences.

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Water Problems and Issues of Ohio

Water is one of Ohio's most important natural resources. Bounded on the north by Lake Erie and on the south by the Ohio River and containing other extensive ground and surface waters, Ohio has an adequate supply of water to meet its immediate needs. However, the combination of large, heavily industrialized urban centers; extensive agricultural activities; high volume coal production and large coal reserves; and the associated demands of new energy production continues to cause concerns related to water quality and water management. In addition, extreme hydrologic events cause localized problems of both excessive water and deficiencies at times.

Surface Water

The northern 25 percent of Ohio's area drains into Lake Erie, while the southern portion drains into the Ohio River. Runoff from Ohio's streams and rivers averages about 25 billion gallons per day. The state also receives nearly a billion gallons of runoff daily which drains through the Maumee River to Lake Erie from the neighboring state of Indiana; and Ohio has access to additional flows past its boundaries in Lake Erie and the Ohio River that total well over 150 billion gallons of water per day.

Last year, more than 16 billion gallons of water were withdrawn from Ohio's surface sources each day to meet the demands for municipal supplies; rural needs for domestic and livestock purposes; irrigation; and self-supplied industrial needs including cooling water for thermo-electric power generation. These demands account for only 60 percent of the available surface waters in the state's streams each day, and localized shortages only develop during certain dry seasons and periodic droughts.

The combined length of all the streams in Ohio approaches 44,000 miles, which means that there is approximately one mile of stream for each square mile of surface area in the state. In addition, there are more than 50,000 lakes, ponds and reservoirs within the state having a combined surface area of 200,000 acres. Only a small fraction of these, about 6,700 acres, occur naturally. The remainder are man-made impoundments that range in size from small farm ponds to large multipurpose reservoirs.

The reservoirs in the state are used to provide water for many different purposes including municipal, agricultural and industrial supplies; stream flow augmentation; flood control; and recreation. No impoundments in Ohio, other than those on the main stem of the Ohio River, provide water for downstream navigation or hydro-electric power generation. However, there is extensive navigation on both Lake Erie and the Ohio River, and consideration is being given to the installation of low-head hydro-electric generators at several developed dam sites throughout the state.

Flooding, still a major problem in Ohio, affects both urban and agricultural areas; and it has been estimated that nearly two million acres of land in Ohio are flood prone. This represents over seven percent of the total area of the state and includes nearly four percent of those areas classified as urban regions. Average annual flood damages in Ohio vary from year-to-year but amount to several millions of dollars annually.

Ground Water

Ground water is an important part of Ohio's water resources. Ground water underlies most of the state but is predominant in the glacial drift in the northwest, in the ice-contact and outwash deposits in river valleys along the border of the glaciated areas, and in the bedrock of the western portions of the state. Ground water supplies are largest in the glacial valley-train deposits in those drainage basins which border the Ohio River including the Ohio, Miami, Little Miami, Scioto, Hocking and Muskingum Rivers. Well yields from these deposits often exceed 500 gallons per minute (gpm), while aquifers in the glacial drift in the northwest and west-central parts of the state produce yields between 100 and 500 gpm. With the exception of the valleys along the major streams, most of the aquifers in the area that is tributary to the Ohio River have yields less than 5 gpm.

Three-quarters of Ohio's 650 public water supply systems use ground water as their source. In terms of volume withdrawn, however, a lesser share of these supplies comes from ground water, for only around a half billion gallons of ground water are withdrawn each day for public water supply purposes, while over one billion gallons come from surface water sources. However, ground water supplies nearly 80 percent of the rural water needs in Ohio, 32 percent of the irrigation waters and 21 percent of the industrial water demands. Nearly one billion gallons of ground water are withdrawn in the state each day to meet these needs.

Water Quality

It is the quality of water, rather than its quantity, that is the more critical and limiting condition associated with the use of both ground and surface waters in Ohio. The ground waters of the state frequently have relatively high, natural mineral contents; but, except for a few local areas, most of these waters are free from man-related contamination. Most complaints are related to increased levels of turbidity, bacterial populations and other substances from improperly sited or poorly constructed or maintained wells. Other problems are related to the spillage and leakage of brines and petroleum at oil wells in the southeastern part of the state; the mis-application of pesticides, herbicides and insecticides in agricultural areas; and the improper siting and operation of solid and liquid waste disposal facilities. Some minor ground water problems associated with the excessive use of highway de-icing salts or its improper storage have also been reported.

The dissolved solids concentrations in Ohio's streams range between 120 and 2,500 milligrams per liter (mg/l). The higher concentrations are found in Tuscarawas, Cuyahoga and Grand Rivers and in other stream reaches below major municipal and industrial outfalls or in areas subjected to diffuse source runoff.

Of the 23,000 miles of the principal rivers downstream of major urban areas in the state that have been monitored, 16,000 miles, or 70 percent of these streams, meet the current water quality standards. Where problems do exist, they are frequently caused by inadequate municipal wastewater treatment at facilities that need to be upgraded or expanded, or by combined sewer outflows.

Substantial improvements in surface water quality have resulted from the development of pretreatment regulations for industrial waste discharges to municipal sewerage systems. Violations of the state's water quality standards occur most often in dissolved oxygen levels; ammonia nitrogen concentrations; the numbers of the fecal coliforms; and the levels of heavy metals such as lead, zinc, and cadmium.

Acid mine drainage is a major cause of water quality problems throughout the Appalachian Coal Basin in the eastern United States. In Ohio this region extends in a band approximately 50 miles wide in a southwesterly direction from the east-central to the south-central parts of the state. Acid drainage from abandoned and improperly operated or reclaimed coal mined lands causes a loss of water for domestic and industrial uses; the degradation of water quality for recreational purposes; a lethal impact on the aquatic life in a stream; and an accelerated deterioration of highway and railroad bridges and electrical transmission lines and towers. Drainage from abandoned coal mines, both surface and underground, has impacted around 1,500 miles of streams in 27 counties in southeastern Ohio. Approximately 370,000 acres of abandoned strip mines, 7,000 acres of coal refuse piles and 3,000 underground mines are contributing to this problem. It has been estimated that four billion dollars would be needed to reclaim the abandoned mines and refuse piles throughout Ohio. Projected revenues from severance taxes earmarked for abandoned mine reclamation come to about ten million dollars annually. Obviously, the technologic problems and the economic costs association with the control of acid mine drainage will continue to keep this a major problem of water quality in southeastern Ohio for years to come.

Little detailed information is available concerning the impacts that diffuse sources of pollution such as agricultural and urban storm water drainage have on the quality of water in Ohio's inland streams. One concern with non-point pollution is the sediment that is dislodged from the land surface and carried to these streams. Of greater concern are the pollutants, such as the nutrients, heavy metals and toxic organic substances, that enter the streams attached to the sediments. No need for intensive, non-point source control programs to meet water quality standards in that area of the state that drains to the Ohio River has been shown; but several studies are underway in the Lake Erie drainage basin to define the role of agricultural drainage on the water quality in the lake. Much more research and many more demonstration projects on the best management practices for agriculture, silviculture, mining and urban runoff control must be conducted before this problem is fully understood and control measures can be instituted.

The trophic status of several lakes and reservoirs has been studied; and the results suggest that the lakes and reservoirs in the sandstone bedrock areas of the state have generally lower trophic levels than those in the limestone bedrock areas or glaciated regions. Water quality was generally good to excellent in most of the lakes and reservoirs surveyed. However, excessive concentrations of copper and other heavy metals, bacteria and other pollutants normally associated with urban activities were identified in some of the lakes. Recent studies on Lake Erie indicate that there has been a reduction in several key pollutants and a gradual, but steady, improvement in the water quality in the Lake during the past few years. Phosphorus is a major pollutant which results in the excessive growth of algae and other aquatic plants. As these plants die and decay, they deplete the oxygen resources of the Lake. The construction of facilities to remove phosphorus at those municipal wastewater treatment plants which discharge directly to Lake Erie has been a major factor in the reduction of phosphorus loadings and of the subsequent reduction of the anoxic areas within the Lake. Additional work on the control of phosphorus from both diffuse sources and point sources needs to be accomplished, but a significant start has been made.

Levels of bacteria have been reduced in the nearshore zones where municipal wastewater treatment facilities have been constructed. This has permitted regulatory agencies to re-open bathing beaches which were often closed during the period between 1960 to 1970. Concentrations of mercury and pesticides have been reduced substantially, principally because of the federal bans that have been instituted on their manufacture, use and disposal. PCB remains a major challenge, as does the control of sediment and the nutrients, fertilizers and organic chemicals that are attached to it.

Fish populations, including the walleye pike, are beginning to increase again in the lake; but the quality and diversity of fish is still far from what they were in the past. Thermal pollution is a localized problem in some near-shore areas. However, as closed cycle cooling is required on all power generation facilities, the extent of this problem will diminish.

Program Goals and Priorities

The Water Resources Center at The Ohio State University encourages and supports research that is directed at providing information needed to solve the major water problems at the local, state, regional and national levels. The research program at the Center includes basic or fundamental research, problem oriented or applied research, and information dissemination and technology transfer activities.

During FY 1982, the Center, in cooperation with several groups of water-related agencies and officials throughout the State prepared a prioritized list of Ohio's major water resources problems. Based upon this analysis, the following ranking of these problems was developed:

1. **Pollution from diffuse sources** - including agricultural runoff, urban runoff, runoff from on-site waste disposal systems; runoff from active, reclaimed or abandoned coal and strip mines.

2. **Contamination of drinking water supplies** - including surface and ground waters for both urban and rural uses by diffuse and point sources, and by the disposal of toxic and hazardous wastes on the land.

3. **Toxic and hazardous waste disposal** - including their control, treatment, disposal and impact upon land, water and air resources.

4. **Pollution from point sources** - including municipal and industrial sources not yet in compliance with their NPDES permits.

5. **Impacts of flooding and drainage** - including flood damages, the use of flood plains and alternative structural and non-structural means of controlling floods and reducing flood damages.

6. **Impacts of water resources developments** - including the impacts on various developments such as the extension of water mains and sewers into rural areas' flood control projects; hydro-electric power generation; water-based recreation, etc.

7. **Instream flow needs** - including interrelationships among water quality, water quantity and land use practices on the instream flow needs for fish, wildlife, recreation and the optimum development and protection of these instream uses.

8. **Impacts of synthetic fuel development** - including requirements for water and impacts of he disposal of wastes from these processes into water and onto the land.

9. **Impacts of atmospheric pollution** - including the effects of acid precipitation and atmospheric fallout on water quality and the environment.

10. **Allocation of water resources** - including the development of contingency plans for the allocation and conservation of limited water supplies among competing water users during periods of low stream flows.

Subsequently, the Directors of the Water Resources Research Institutes in the Great Lakes, Upper Mississippi and Ohio River Basin's met to identify from their State problems the major water resources research priorities for the Region. A listing of these priorities is included at the end of this Section of this Report.

The focus of the 1995 State Water Resources Research Program was primarily directed at some of these critical needs. The technology transfer programs of the Water Resources Center continued to disseminate information about the water resources of Ohio to the local and state decision-makers, and provides technical assistance to help resolve some of the state's major water problems. Three research projects were continuation projects of the FY 1995 water resources research program and the technology transfer program substantially expanded the development of the Ohio Water Education Program area.

The technology transfer program continued to work closely with the water professionals throughout the state and nation in cooperative efforts, jointly sponsored programs, newsletters and reports. The Ohio Water Education Program, (OWEP) provides current information on all water education activities in Ohio and helps teachers network. It also provides K-12 water resources education through Project WET. Ohio State has the lead in a seven state pilot project with the Department of Energy, on environmental management and restoration of DOE sites.

The project at Miami University by Drs. James B. Finley and Jonathan Levy , studied the "Herbicide Contamination of Surface and Ground Water in the Four Mile Creek Drainage Basin". This research was a fate and transport study of agricultural chemicals in the drainage basin which had a city in the region that uses the water as its main source of drinking water.

The research by Dr. Susan Fisher, through the Department of Entomology at The Ohio State University, "Critical Body Burdens for the Biological Effects of Dioxins in Aquatic Biomonitors and Applications to a Risk Assessment Model", studied how invertebrates responded to different concentrations of dioxions- by critical body burdens - of acute, chronic and sublethal reactions. This basic research information ultimately will provide a framework for the assessment of ecological risk in aquatic foodchains.

Professor Shang-Tian Yang, Department of Chemical Engineering at The Ohio State University studied, "A Novel Fibrous-Bed Immobilized Cell Bioreactor for Bioremediation of BTEX". Many industrial processes use benzene, toluene, ethylbenzene and xylenes (BTEX) which are water-soluble, toxic components of gasoline. Developing a bioreactor to remove these contaminants in a economical and efficient method using bioremediation is the objective for this applied research project.

SYNOPSIS

Project Number: 02

Start: 07/95 (actual)
End: 06/96 (actual)

Title: Herbicide Contamination of Surface and Ground Water in the Four Mile Creek Drainage Basin

Investigators: Levy, Jonathan; Finley, Jim; Swartwout, Robert; and O'Malley, Lorie; Miami University, Oxford, Ohio

Focus Categories: AG, GW, HYDGEO, HYDROL, NPP, SW, WQL

Congressional District: Eighth

Descriptors: groundwater movement, groundwater quality, contaminant transport, herbicides, atrazine, metabolites, deethylatrazine, deisopropylatrazine, movement, persistence

Problem and Research Objectives: The Four Mile Creek valley is an agriculturally rich area are underlain by glacial deposits. Acton Lake reservoir divides the Four Mile Creek basin into two sub-basins. In the valley upstream (north) of Acton Lake, the glacial deposits comprise mostly till overlying shale and limestone bedrock. Down-valley, the deposits include a glacial outwash aquifer that is the principal source of drinking water for the City of Oxford and its surrounding community. The primary crops are corn, soybeans, and occasionally wheat. It is normal practice to protect the harvest with a variety of pesticides, many of which contain one or more of the compounds termed triazines. Atrazine [2-chloro-4-ethylamino-6-isopropylamino-*s*-triazine] is the world's most commonly used triazine for corn. Atrazine is considered a possible carcinogen by the U.S. EPA due to the incidence of cancer in laboratory animals (U.S. EPA 1994). When atrazine enters the soil it begins to degrade by several processes. The compounds that it degrades into are chemical degradation products (degradates) and microbial degradation products (metabolites). Some of these degradation products may be as or more toxic to humans than their parent compound. Two of Oxford's municipal water wells are located adjacent to or in the middle of agricultural fields. Depending on the fate of atrazine and its metabolites and the flow characteristics of the Four Mile Creek aquifer, atrazine contamination could represent a health hazard for recipients of city water.

This study's main objective is to determine the extent and distribution of atrazine and its metabolites (1) in the glacial outwash aquifer of the Four Mile Creek valley south of Acton Lake, and (2) in the drainage basin upstream of Acton Lake. We hope to eventually be able to infer relationships between the spatial and temporal distribution of atrazine and its metabolites and the time of contaminant travel down gradient from fields of application. These objectives require the characterization of the hydrogeology of the aquifer. Specific objectives therefore, are:

Accurately describe the hydrogeologic characteristics of the Four Mile Creek aquifer.

Determine extent of groundwater contamination by atrazine and metabolites. Compare groundwater contamination patterns down gradient from agricultural fields with varying application histories.

Determine if ratios of atrazine to metabolite concentrations relate to the contaminant travel time and distance through glacial outwash aquifer.

Assess the severity and threat of pesticide contamination to drinking water in the Four Mile Creek aquifer.

Background - Atrazine [2-chloro-4-ethylamino-6-isopropylamino-*s*-triazine] was introduced in 1953 as a preemergent herbicide used to protect broadleaf crops such as corn. An estimated 90-120 million pounds of triazine pesticides are used annually, about 80 percent is used on corn (U.S. EPA 1994). According to a proposal for a pesticide management plan by the Ohio Coordinating Committee on Ground Water (1995), Ohio ranks fifth in the nation in agricultural pesticide use at 14.5 million kilograms/year, and by 1993, atrazine was the most widely used pesticide in the state.

In the United States atrazine detection in groundwater is commonly 10 to 20 times more frequent than the next most frequently detected pesticide (Belluck *et al.*, 1991). Current information has led the U.S. EPA to conclude that atrazine is a possible carcinogen based on the incidence of mammary tumors in female rats (Belluck *et al.*, 1991). The U.S. EPA-proposed Maximum Contaminant Level (MCL) is 3 ppb atrazine in drinking water. It is estimated that a daily exposure of 0.3 ppb of atrazine in drinking water (assuming a person consumes 2 liters of water per day containing atrazine at 3 μg/L over a 70-year lifetime) poses a one-in-a-hundred-thousand lifetime cancer risk (U.S. EPA, 1994). Referring to the toxicity of atrazine metabolites, Ciba-Geigy, the manufacturer of atrazine, has been quoted as stating that "the principal metabolites have toxicities which equal or exceed that of the parent" (Belluck *et al.*, 1991).

"Parent" refers to the compound originally introduced into the environment before it has undergone any transformations. In this case, the parent compound is atrazine. Once introduced into the environment the parent compound can then undergo degradation through several pathways creating what are known as chemical degradation products or metabolites. Degradation in the context of groundwater contamination is defined as the process of an organic molecule becoming smaller by chemical or biological means.

Chemical degradation of atrazine through hydrolysis results in the formation of hydroxyatrazine. Hydroxyatrazine is less toxic and, therefore, less of a risk to human health than atrazine's chlorinated metabolites (Anderson *et al.*, 1990). Investigations in various soils have found hydroxyatrazine to be the principal degradation product of atrazine (Muir and Baker, 1978; Dao, 1977) and the rate of atrazine hydrolysis to increase with temperature (Bacci *et al.*, 1989; Armstrong *et al.*, 1967). While most investigations have been performed in unsaturated, relatively warm surface soils, Wehtje *et al.* (1984) found hydroxyatrazine to be the only major degradation product in a saturated, 12°C aquifer sand.

Microbial degradation of atrazine results in dealkylation and generally occurs above the water table, primarily in the root zone (Wehtje *et al.*, 1984). Dealkylation constitutes the removal of either one or both of the alkyl side groups from the triazine ring yielding deethylatrazine (DEA), deisopropylatrazine (DIA), and diamino-chloro-*s*-triazine. At least 5 species of bacteria and 21 species of fungi are effective in metabolizing the alkyl side chains of atrazine. Some bacterial species prefer deethylation while other species prefer deisopropylation (Adams and Thurman, 1991). Various field and laboratory studies have reported DEA as the prominent dealkylated metabolite of atrazine, with DIA present often only at trace concentrations (Adams and Thurman, 1991). Consequently, DIA may be a metabolite of minor importance in the degradation reactions of atrazine (Mills and Thurman, 1994). Whether through hydrolysis or microbial degradation, atrazine in groundwater may have a half-life of anywhere between 70 days (Blum *et al.*, 1993) to 3470 days (Levy and Chesters, 1995).

Most of the studies dealing with atrazine transport are primarily concerned with its transformation and movement in the soil zone and not with what happens once it has reached the groundwater. The primary focus of this study is to understand and try to quantify the observed processes which take place after atrazine has already reached the groundwater.

<u>Methodology</u> A. Site Selection, description and land use.This study focuses on four agricultural fields in southwestern Ohio. The land is owned by Miami University and the fields are leased for private agricultural production. The site was chosen primarily because the underlying glacial outwash aquifer is typical of unconsolidated aquifers in southwest Ohio. Furthermore, the aquifer is the main source of water for the City of Oxford. The field site is roughly 40 hectares and is located about 0.5 km east of Oxford, Ohio on the north side of State Route 73 (Fig. 1). The fields are mostly flat with up to a 2% slope to the west where they are bordered by Four Mile Creek. The fields are farmed with a rotation of corn, soybeans, and occasionally wheat. The corn receives an application of Bicep® which contains roughly 27% atrazine. The soil comprises loams from the Genesee and Ross series which are typically deep, well drained, moderately permeable soils that form on flood plains.

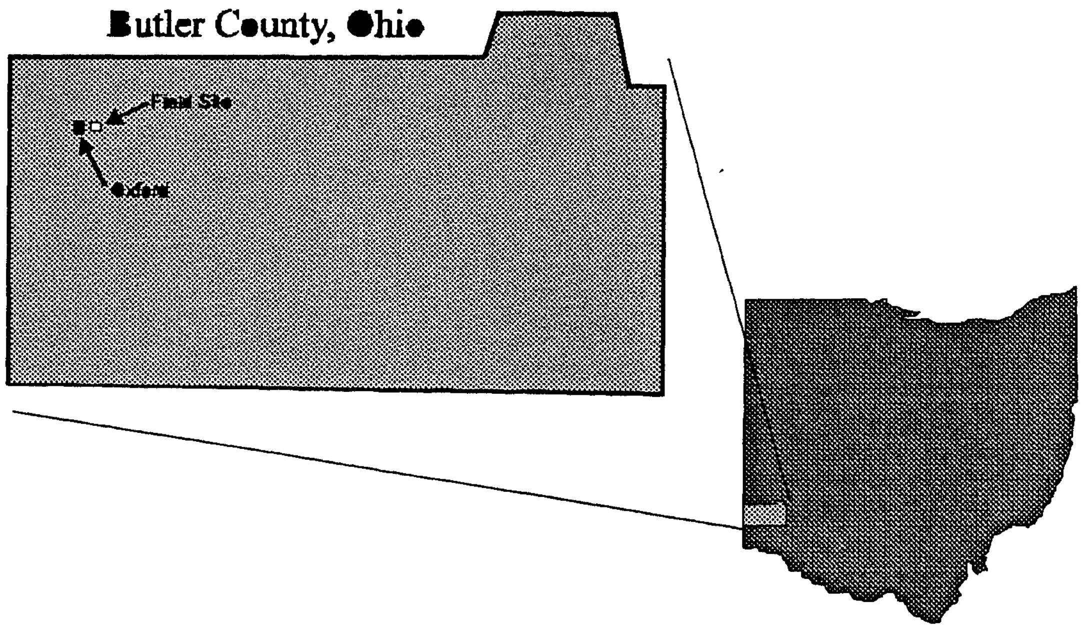

Figure 1. Four Mile Creek field site

The Four Mile Creek Valley was initially carved into the pre-existing interbedded limestone and shale bedrock by a river during the early Pleistocene epoch. During this time, the valley floor was eroded far below the present elevation of the valley bottom. During advances and retreats of glacial ice the valley was filled with alternating layers of sand-and-gravel outwash, lacustrine silts and clays and glacial till. The outwash deposits are typically very permeable and are potential aquifers when saturated. The till is a dense mixture of gravel, sand, silt and clay with relatively very low permeability, and acts as a confining unit to groundwater movement. Throughout much of the basin, outwash extends from near the surface to depths between 6 and 18 m. It is underlain by a till unit which is typically 15 to 20-m thick. The outwash itself is very heterogeneous with beds of various grain sizes probably ranging from a few centimeters to a few meters in thickness. The water table typically lies between 2 and 3.5-m below ground surface due to seasonal variability.

B.Borehole Installation and Sampling.A monitoring well network has been installed in the Four Mile Creek Valley using Miami University's hollow-stem auger drilling rig. To date there are wells in 15 different locations with nested wells in 7 locations (Fig. 2). The augers, drilling rods, and split-spoon sampler are cleaned before drilling to prevent cross-contamination between wells.

The wells are constructed of 1.25-in inner diameter flush-threaded PVC casing and slotted PVC screens. Most screens have a slot size of 0.020-in and are 5-ft in length. Well nests comprise one well screened at or near the water table (labeled as B, Table 1), and one well screened just above the till layer (labeled as A, Table 1). A filter pack of sand is installed by gravity to 1-2 ft above the screen.

The hole is sealed from the filter pack to the ground surface with gravity-emplaced 3/8-in bentonite chips (Fig. 3).

During each deep-borehole drilling the aquifer material is sampled using a 2-in diameter by 2-ft long split-spoon sampler. Sample cores are collected in plastic tubes lining the split-spoon sampler. The borehole samples are used to help characterize and log aquifer stratigraphy, and for laboratory tests of grain size and permeability.

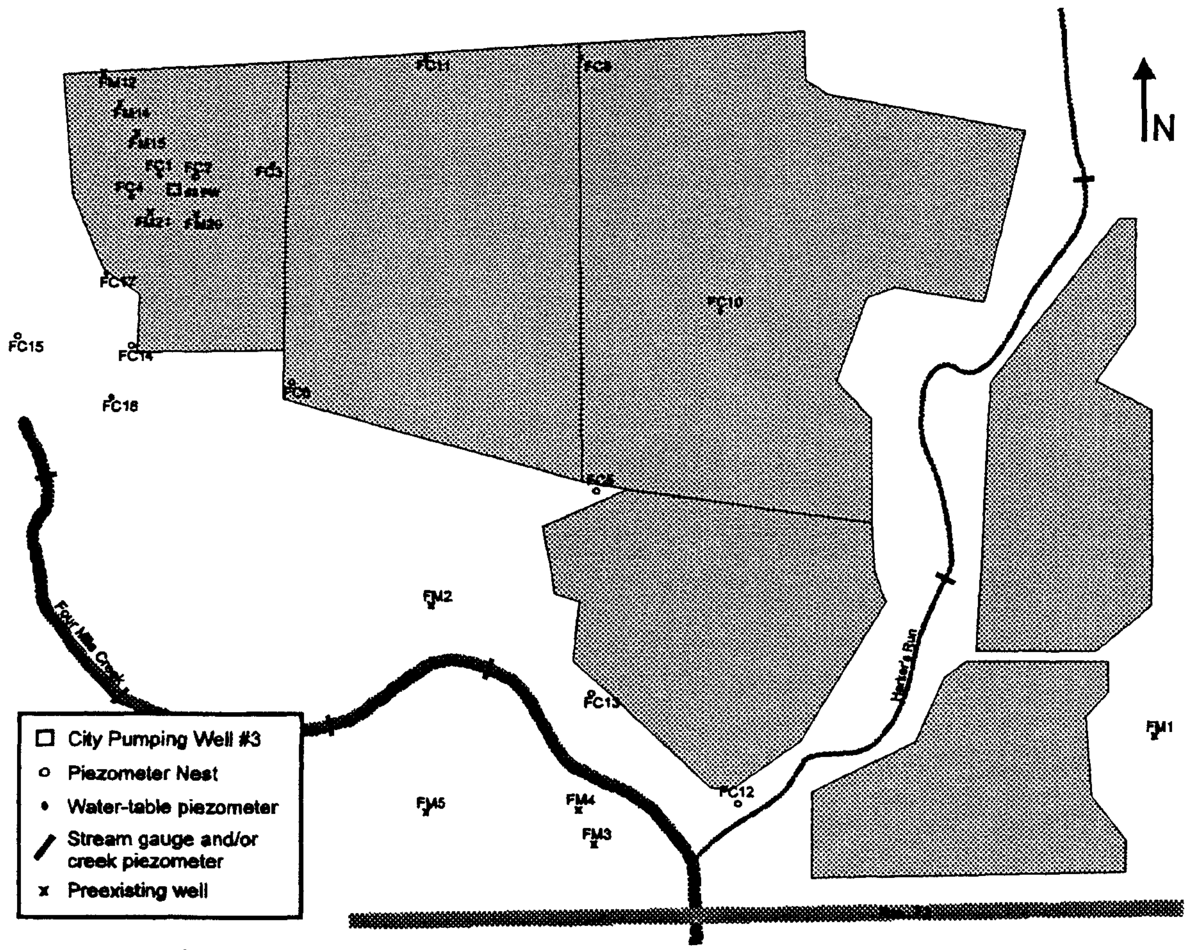

Figure 2. Monitoring well network at the Four Mile Creek field site

Well	Date Installed	Elevation of Top (ft)	Total Depth (ft)	Elevation of Bottom (ft)	Screen Length (ft)	Inner Well Diameter (ft)
FC1A	6/19/95	787.4	45	742.4	30	0.17
FC2A	6/20/95	787.6	39	748.6	5	0.17
FC2B	6/28/95	786.7	27	759.7	5	0.11
FC2C	6/29/95	787.1	15	772.1	5	0.11
FC3A	6/29/95	786.7	19	767.7	5	0.11
FC4A	7/8/95	785.1	40.5	744.6	5	0.11
FC5A	12/15/95	787.4	25.1	762.3	5	0.11
FC5B	1/25/96	787.1	12.5	774.6	5	0.11
FC6A	2/8/96	787	40	747	5	0.11
FC6B	1/29/96	784.8	9.25	775.55	5	0.11
FC8A	2/6/96	792.5	12.7	779.8	5	0.11
FC10A	2/19/96	786.2	15	771.2	5	0.11
FC11A	NA*	786.9	NA	NA	5	0.11
FC12A	3/12/96	783.3	27.5	755.8	5	0.11
FC12B	3/14/96	783.2	16.5	766.7	5	0.11
FC13A	7/19/96	782.4	33	749.4	5	0.11
FC13B	3/16/96	782.9	17.75	765.15	5	0.11
FC14A	6/2/96	786.6	29	757.6	5	0.11
FC14B	3/26/96	786.5	12	774.5	5	0.11
FC15A	NA	786.3	25.5	760.8	5	0.11
FC15B	3/26/96	785.3	13.5	771.8	5	0.11
FC16B	4/9/96	785.3	13.75	771.55	5	0.11
FC17B	4/18/96	786.7	20	766.7	5	0.11

Table 1. Monitoring well design and elevation data (* Not available)

Stream gauges and mini-piezometers driven into the bottom of Four Mile Creek have been installed to provide information concerning processes governing groundwater/surface water interaction in the valley. Mini-piezometers are made of 0.5-in outside diameter polyethylene tubing and are used to measure hydraulic head differences between the creek and underlying aquifer. Such head differences indicate whether groundwater discharges to the creek or vice-versa. Stream gauges are installed next to the mini-piezometers so that mini-piezometer elevations can be measured and heads compared with those in the wells.

Through the use of direct punch wells we will expand our monitoring well network to include those areas previously unreachable with the drilling rig. These wells will be installed using a portable tripod and drive weight to drive the wells into the ground to the desired depth.

C. Hydrogeologic Investigation. Hydraulic heads are monitored and head data are used to determine groundwater flow direction and horizontal and vertical head gradients. In the field initial horizontal conductivities were measured using rising head slug tests, and data were analyzed using the Bouwer and Rice (1976) method. In the laboratory, constant head permeameter measurements are being used to determine vertical conductivities.

D. Water Sampling and Analysis. A water sampling program has been initiated to determine the extent of atrazine in surface and groundwater and to monitor the temporal changes in concentration distribution. Water samples are not taken from preexisting wells because their design is of some debate and well construction may have some effect on concentrations of compounds in the well water. Before samples are taken the wells are purged of 3 to 4 well volumes. Equipment that comes in contact with a water sample is cleaned with detergent, rinsed with tap water, rinsed with deionized water, and finally rinsed with methanol. PVC gloves are worn by field technicians and a new pair are put on for each new task, in order to prevent cross-contamination. Samples are collected using a 3-ft long stainless steel bailer and poured into 1-L amber bottles. Samples are stored at 2 - 8°C until analysis.

Separate samples for major cation and anion (including NO_3^-) analyses are collected and filtered in the field using a 0.2 μm cellulose nitrate filter membrane. To prevent precipitation during storage, 1 molar HNO_3 is added to the sample to be analyzed for major cations; enough acid is added to lower the pH to ≤ 2. Water quality analysis also includes field-measured pH, dissolved oxygen content, specific conductance, and temperature.

The RaPID Assay system for atrazine, produced by Ohmicron® (Herzog, 1993), has been used to collect preliminary atrazine and metabolite concentration data for the groundwater samples. The immunoassays have a minimum detection of 0.046 ppb atrazine and are relatively inexpensive and fast. One drawback of this system is that it does not distinguish between the respective concentrations of atrazine and its metabolites.

We will also be using High Performance Liquid Chromatography (HPLC) to analyze water samples for their respective concentrations of atrazine and its degradation products. Before samples are ready to be analyzed they must first be filtered using a 0.2 μm cellulose nitrate filter membrane to remove all suspended material that could act as atrazine sorption sites. Extraction of triazine compounds is achieved using the method from Berg *et al.* (1995). Eluded samples are then injected into the HPLC. Unfortunately, the HPLC has been inoperative since Spring 1996 and the complete analysis of atrazine and its metabolites has not yet been completed. Thus the balance of the report will focus on the data obtained using the immunoassay technique.

Principal Findings and Significance.A. Hydrogeology. Groundwater flow within the study area is generally northeast to southwest towards Four Mile Creek (Fig. 4). Seasonal variation in the water table seems to be between 2 and 3.5 meters below the land surface for most wells in the field area. The horizontal hydraulic gradient averages 0.006 over the whole study area.

Slug tests on some of the wells in the field area have yielded initial horizontal conductivities for the aquifer. The Bouwer and Rice (1976) method was used to analyze the data. The values of horizontal conductivity range from 1.1×10^{-4} to 2.0×10^{3} meters/second with a geometric mean of 6.7×10^{-4} meter/second. Assuming a porosity of 0.3 (Freeze and Cherry, 1979), the groundwater flow velocity averages 1.3×10^{-5} meters/second or 1.2 meters/day across the entire study area.

Constant head permeameter measurements in the laboratory have produced vertical conductivities ranging from 1.6×10^{-6} to 7.3×10^{-4} meters/second with a geometric mean of 7.1×10^{-5} meters/second.

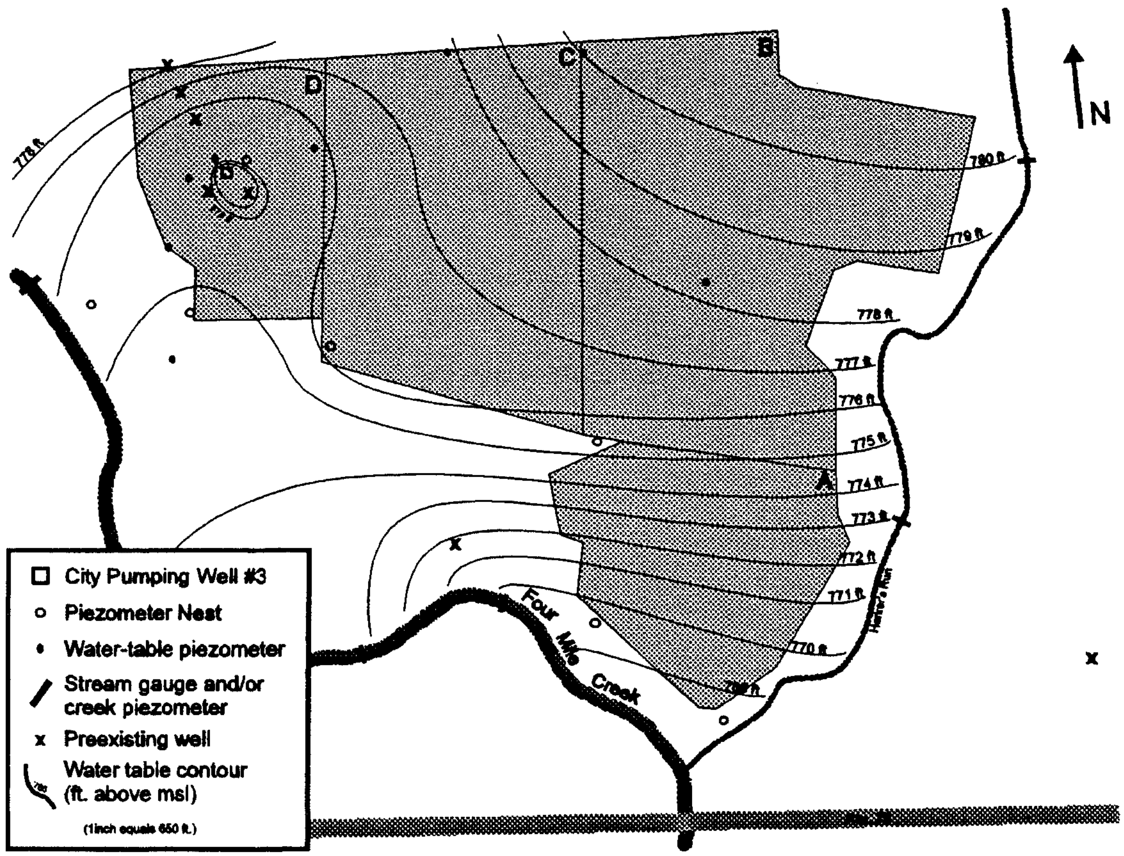

Figure 4. Four Mile Creek study area. Water table elevations from July 30, 1996.

B. Water Chemistry. An initial anion analysis of the first sampling round (before pesticide application) has revealed atrazine concentrations that may lead to a better understanding of the source of groundwater being sampled and the flow paths within the valley (Table 2). Hopefully as more samples are analyzed trends in the data will become apparent.

Sample	Cl^-	NO_3^-	PO_4^{3-}	SO_4^{2-}
FC1A	16.94	33.61	ND*	27.03
FC2A	18.06	NA*	ND	76.89
FC2B	18.08	24.68	ND	40.21
FC2C	16.22	36.16	ND	42.19
FC3A	10.45	16.30	ND	38.96
FC4A	19.19	NA	ND	69.19
FC5B	15.66	18.94	ND	34.24
FC6A	8.74	NA	ND	34.01
FC6B	11.2	4.87	ND	11.75
FC15B	11.64	30.88	ND	15.76
FC16B	12.82	27.05	ND	24.02
FC17B	18.38	26.05	ND	32.42

All results are reported in units of ppm (mg/L).
*NA - not tested, *ND - not detected

Table 2. HPLC anion analysis results for the groundwater samples collected in the first sampling round

C. Results of Atrazine Analysis.Initial immunoassays have revealed concentrations of atrazine in some wells for two different sampling rounds. The sampling round starting June 6, 1996 was only a partial sampling round that did not include samples from all wells (Fig. 5). With one exception, all the wells showing the largest concentrations are located in and down gradient from field D. The sampling round starting July 23, 1996, included all of the wells and once again, with one exception, all of the highest concentrations are localized in and around field D (Fig. 6). The sampling rounds both occurred after field D's pesticide application of June 1, 1996. This combined with the spatial distribution of the atrazine detections suggests that the contamination of the groundwater is derived from the pesticide applied to field D. Hopefully with continued sampling and the expansion of the sampling network, distributions of atrazine concentrations down gradient from field D will continue to be observed.

There are no HPLC data at this time. However, all samples have been extracted onto carbon filters and are awaiting analysis.

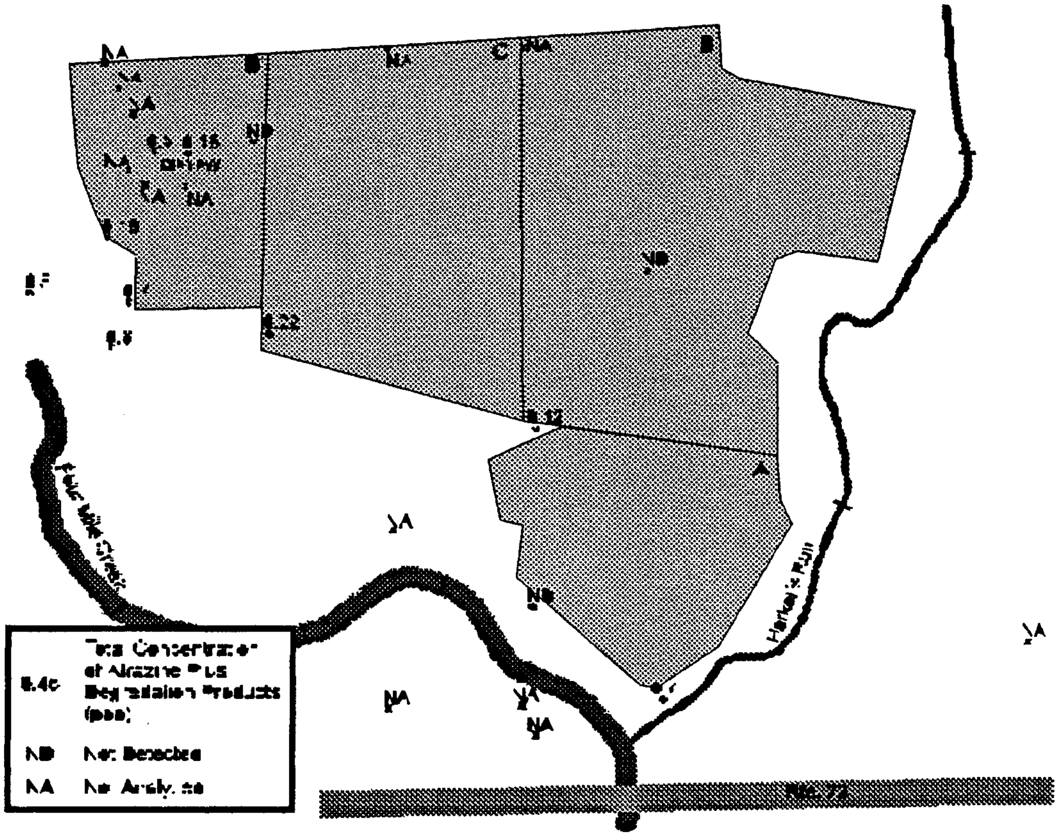

Figure 5. Atrazine concentrations from samples collected 6/3/96-6/5/96

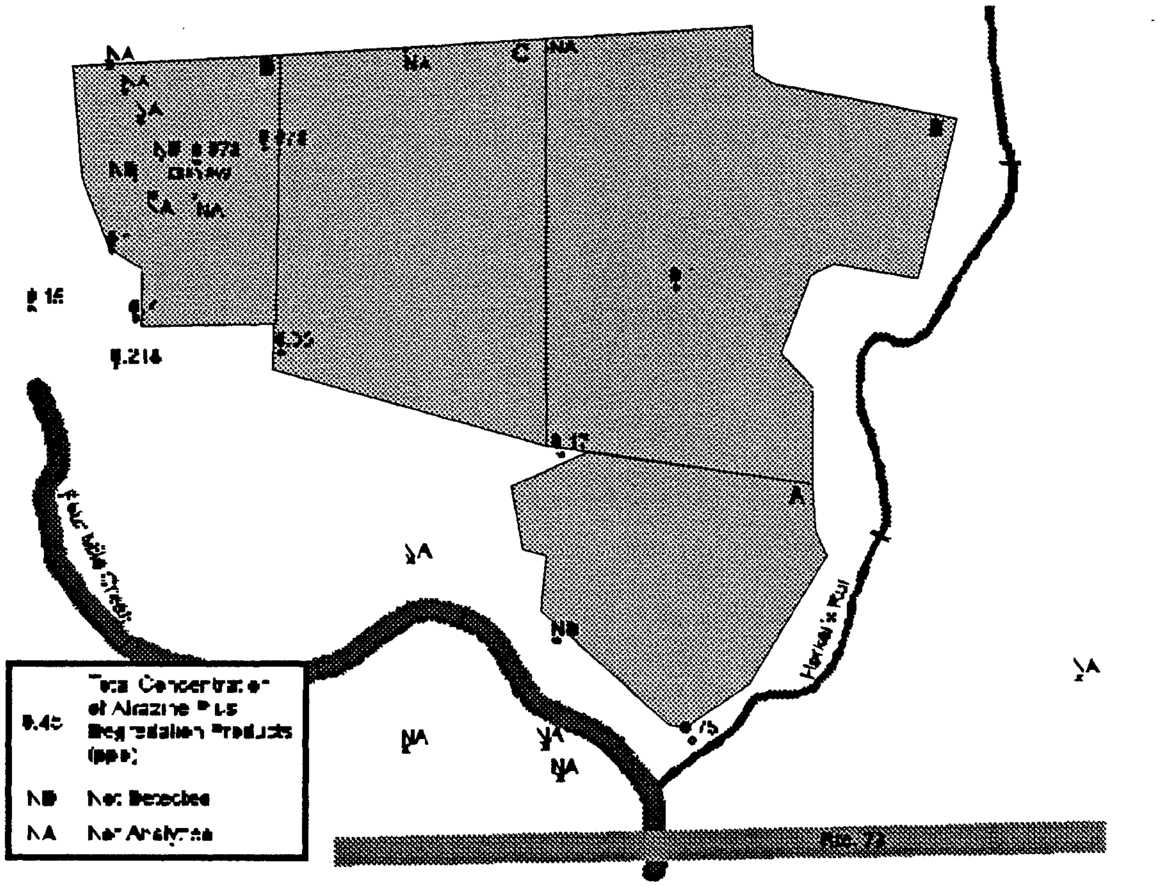

Figure 6. Atrazine concentrations from samples collected 7/23/96-7/26/96.

Continuing Research. Groundwater sampling will continue into late fall/early winter 1996. Efforts are being made to increase the sampling points down gradient of the agricultural fields by putting wells in the wooded areas between the fields and Four Mile Creek. Continued monitoring of the water table may reveal seasonally changing groundwater flow patterns that could have an effect on the nature of the distribution of contamination. HPLC analysis will produce respective concentrations for atrazine and its metabolities and may yield interesting data concerning the relative degradation of atrazine with time and distance down gradient from agricultural fields.

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Belluck, D. A., Benjamin, S. L., and Dawson, T., (1991) Groundwater contamination by atrazine and its metabolites: risk assessment, policy, and legal implications. pp. 254-273. In: Somasundaram, L. and Coats, J. R. (eds.). Pesticide transformation products: fate and significance in the environment. ACS Symp. Ser. 459. American Chemical Society, Washington D. C.

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Publications

5. Conference Proceedings

Swartwout, Robert; Levy, Jonathan, 1996, Extent and distribution of groundwater contamination from atrazine and atrazine metabolites in a buried-valley aquifer in southwest Ohio, in the Forty-first Annual Midwest Groundwater Conference, Lexington, KY.

Training Accomplishments. This project has been partial training of one Master's student in Geology.

SYNOPSIS

Project Number: 03

Start: 7/95 (actual)
End: 6/96 (actual)

Title: Critical Body Burdens for the Biological Effects of Dioxins in Aquatic Biomonitors and Applications to a Risk Assessment Model

Investigator: Fisher, Susan W., Ohio State University

Focus Categories: WQN, TS, NPP

Congressional District: 15

Descriptors: Bioindicators, Hazardous Waste, Health Effects, Pollutants, Risk Analysis, Toxic Substances, Water Quality Control

Problem and Research Objectives: The continued presence of hydrophobic contaminants such as polychlorinated biphenyls (PCBs) and polychlorinated dibenzodioxins (PCDDs) in Ohio watersheds raises concerns about potential human exposure and safety. A quantitative evaluation of ecological risk is precluded by lack of data describing the complex relationships between exposure to contaminated media and the resulting biological effects in diverse organisms. Regulatory agencies such as OEPA and ODNR, which are charged with monitoring contaminant levels and assessing hazard, must frequently base regulatory action on an inadequate data base.

This research tested the hypothesis of the Critical Body Burden (CBR) as a direct means of connecting tissue levels of contaminants with the resulting biological effects. Briefly, the hypothesis holds that for a class of chemicals sharing a common mode of action, the amount of contaminant required at the target site should not vary between species or between compounds. This tissue level, or critical body residue, should be useable to assess hazard in a variety of species once the CBR has been determined for a single species. Using several fish species as a model, CBRs for acute membrane narcosis caused by PCB and PCDD intoxication has been measured in the 2-8 mMol/Kg range. In contrast, if aqueous concentrations or sediment concentrations needed to produce those same effects in the same group of species are used, the environmental concentrations needed to cause acute narcosis varies by three orders of magnitude. Using CBRs, then, would seem to have the very valuable effect of dramatically decreasing uncertainty in risk assessment.

CBRs have been determined only for vertebrate species. The research undertaken in this proposal measured CBRs in three species of invertebrates to determine whether invertebrates, particularly those currently used as biomonitors, would show CBRs that were similar to those determined in vertebrate species. Specific research objectives were:

1) To determine CBRs for acute, chronic and sublethal toxicity in 3 species of benthic invertebrates used as biomonitors (*Hyallela azteca*, *Chironomus riparius* and *Lumbriculus variegatus*) using a series of PCBs for which PCDD-activity equivalents have been previously assessed;

2) To determine toxicokinetic parameters for each compound as a means of describing accumulation dynamics and assessing bioaccumulation;

3) To relate tissue concentrations of each contaminant with resulting biological effects and to determine a dose response curve for each contaminant and biological endpoint;

4) To incorporate information on biological effects as determined by CBRs into an ecological risk assessment model.

Methodology: Acute toxicity tests were conducted for each species in static exposures in 1 L beakers using the alga *Chlorella vulgarus* as the source of contaminant. The exposure concentration of each contaminant was varied by adding different amounts of each contaminant to a slurry containing a predetermined mass of algal cells. A total of 5 test concentrations and a control were with 3 replicates of each concentration were used for each compound. The following stages of each organism were used for acute toxicity tests: *C. riparius*, 2nd instar larvae; *H. azteca*, 7-14 d; L. variegatus, adults. Mortality was scored daily for the length of the exposure. Dead animals were removed from the test immediately and analyzed for contaminant concentration. At the conclusion of the exposure, all organisms were killed and analyzed. Chronic toxicity tests were conducted in a manner similar to the acute exposures except that the length of the test was extended and the exposure concentrations averaged approximately one order of magnitude lower than in acute tests. Mortality was monitored every 24 h and tissue residues were measured in all organisms at the conclusion of the test. A variety of sublethal effects and the corresponding body burdens were analyzed for each organism as appropriate to that animal. For midges, whole lifecycle tests were analyzed and body burdens obtained during each stadium were correlated with developmental time within a stadium, weight gain and reductions in fecundity (for pupal and adult stages). For *L. variegatus*, the sublethal effects screened were: weight gain and doubling time. For *H. azteca*, developmental time and fecundity were monitored. Uptake clearance and elimination rates were determined for all organisms and all contaminants according to standard toxicokinetic methodologies which have been used in my laboratory now for 10 years. Toxicokinetic data were analyzed with a two-compartment constant exposure model.

Principal Findings and Significance: **Midges**: Acute narcosis in midges occurred when body residues reached 0.94-1.51 mMol/Kg. At these body residues, 100 % of all midges were killed. In every case, mortality was seen to be concentration-responsive with mortality increasing with graduated increases in exposure concentration. The CBRs for acute narcosis in midges was remarkably consistent among the four contaminants for which the measurement was made and was consistent with CBRs for vertebrate species in the range of 2-8 mMol/kg. Extensive sublethal tests performed with midges again substantiate the consistency of CBRs between contaminants. Of the three endpoints screened in chronic assays, only weight appeared to be relatively unaffected by the presence of contaminants in tissues. There were a few sporadic cases in which significant reductions in weight were seen at higher tissue concentrations, but these were rare and inconsistently found. In contrast, developmental time within a stadium increased significantly with increasing body burden for each developmental stage. Thus, organisms with higher contaminant load took significantly longer to go through the metamorphic stages of the midge life cycle. In addition, there were significant reductions in the number of ova present in female pupae and female adults; the reductions were dependent on the tissue concentration in the midge. In general, the sublethal effects described were manifest at tissue concentrations roughly 1000X below those needed to cause acute narcosis.

The significance of the midge data cannot be overstated. First, the data support the validity of the CBR hypothesis. The tissue contaminant load associated with acute, chronic and sublethal effects do not vary between contaminants as predicted by the hypothesis. Second, the CBRs determined in the midges were identical to CBRs determined elsewhere in vertebrates. Thus, midges would appear to be excellent model organisms for CBRs and are considerably easier to work with that vertebrate species. Finally, the sublethal data show that substantial adverse effects will occur at tissue concentrations 1000X lower than those needed to cause mortality. Thus suggests that serious ecological damage may be done by these contaminants, as evident in the lengthening of the life cycle (lower productivity, increased exposure to predators etc) even though no visible signs of toxicity as we traditionally measure it are present. The significant reductions in fecundity found in both the pupal and adult stages also supports this interpretation and suggests that much of the harm caused by PCB and PCDD intoxication may never be assessed in traditional risk assessments.

Lumbriculus: The lumbricids presented an interesting anomaly in acute toxicity tests. We were unable to kill the lumbricids no matter how high the exposure concentration was increased. Initially this suggested that the CBR must be invalid or carry significant exceptions which might render it functionally useless. However, our analysis of body residues in the lumbricids revealed that, in no case, did the tissue residues come close to the 1 mMol/Kg level that was required for acute narcosis in midges. The toxicokinetic analyses provided an explanation for this apparently aberrant behavior: the elimination rates in the lumbricids was exceptionally high and appeared to increase as the exposure concentration increased. Thus, we were unable to achieve a toxic body concentration, no matter how the exposure concentration went, because the lumbricids have an unusually efficient elimination mechanism. This also explains were lumbricids have been previously reported as being resistant to contaminants. In analyses of sublethal effects, the doubling time of the lumbricids was significant increased in the presence of contaminants. Whereas the number of organisms in the control lower contaminant concentrations increased over time, the number of organisms in the high contaminant exposures actually decreased over time as organisms died and were not replaced through reproduction (usually an asexual process known as budding off). In addition, the mass of individual lumbricids was significantly impacted by the presence of the contaminants. In control groups, biomass increased in each worm. However, organisms held at the higher concentrations lost weight. As with previous tests, the results did not vary significantly as a function of which contaminant the lumbricids were exposed to.

Hyallela: The tests with *Hyallela* are not yet complete owing to difficulty in maintaining the animal in culture. However, those technical problems appear to have been solved and rapid progress is being made in conducting experiments. To date, CBRs for acute narcosis has been measured for four contaminants. The results are very similar to those obtained for midges: at tissue levels around 1 mMol/kg, 100% mortality will occur.

In *toto,* these data support the CBR hypothesis and suggest that it can be used to interpret residue data in diverse species. If the validity of the hypothesis continues to be supported by the data, it will be possible to go back to residue data that has been gathered over the past 2-3 decades and begin to understand the biological significance of those numbers. Moreover, it will become possible to interpret contemporary history using the CBR approach as well. For instance, in evaluating whether remediated sites are actually clean, CBRs can be used to determine whether any adverse effects are likely to result from tissue levels currently detected.

One of the most important findings to come from the current research is the observation that sublethal impacts such as increasing the development time and decreasing reproductive capacities appear to be common. Furthermore, it is relatively easy to quantify significant changes as a function of tissue concentration. Our findings suggest that significant harm is being done to natural populations in ways which would not be easily detectable in standard assays or risk assessment procedures. The ecological importance of these findings merits additional evaluation. At a minimum, the reversibility of these sublethal impacts must be studied. Our toxicokinetic data will be useful in beginning that analysis.

Publications

1. *Articles in Refereed Scientific Journals*

Fisher, S.W. (1995). Mechanisms of Bioaccumulation in Aquatic Systems. Rev. Environ. Contam. Toxicol. 142: 87-117.

Fisher, S.W., H.Hwang, M. Atanasoff and P.F. Landrum (1996). Critical Body Residues for Pentachlorphenol under Varying Conditions of pH and Temperature. In review, Aquat. Toxicol.

2. *Conference Abstracts*

Fisher, S.W., H.Hwang, M. Atanasoff and P.F. Landrum (1995). Critical Body Residues for PCP Intoxication under Varying Conditions of pH and Temperature in the Zebra Mussel. Fifth International Zebra Mussel Research Conference, Toronto, Ontario.

Fisher, S.W., H. Hwang and P.F. Landrum (1995). Critical Body Residues for Lethal and Sublethal Effects of Membrane Narcotics in the Midge, Chironomus riparius. Second World Congress of the Society for Environmental Toxicology and Chemistry, Vancouver, British Columbia.

Publications from Previous Years Based on USGS Funds

1. Refereed Publications

Lydy, M.J., J. Oris, P.C. Baumann and S.W. Fisher (1991). Effects of Sediment Organic Carbon on the Elimination Rates of Neutral Lipophilic Compounds in the Midge, Chironomus riparius. Environ. Toxicol. Chem. 11: 347-356.

Fisher, S.W., M.J. Lydy, J. Barber and P.F. Landrum (1993). Quantitative Structure-Activity Relationships for Predicting the Toxicity of Pesticides in Aquatic Systems with Sediment. Environ. Toxicol. Chem. 12: 1307-1318.

Lydy, M.J., W.L. Hayton, A. Staubus and S.W. Fisher (1993). Bioconcentration of 5,5,6-Trichlorobiphenyl (TCB) and Pentachlorophenol in the Midge, Chironomus riparius as Measured by a Volume Based Clearance Model. Arch. Environ. Contam. Toxicol. 26: 251-256.

2. Published Abstracts

Fisher, S.W., M.J. Lydy and P.F. Landrum (1991). QSARs for Predicting the Toxicity of Cholinergic Pesticides in Aquatic Systems with Sediment. Soc. Environ. Toxicol. Chem. 11th Annual Meeting Abstracts, Seattle, WA.

Kallander, D.B. and S.W. Fisher (1992). Quantitative Structure Activity Relationships for Predicting the *In Vivo* Inhibition of Acetylcholinesterase in the Midge, Chironomus riparius. 13th Annual Meeting of the Soc. for Environ. Toxicol. Chem. Abstracts, Cincinnati, OH.

Hwang, H. and S.W. Fisher (1995). Predicting the Toxicity of Pesticides Using Quantitative Structure Activity Relationships. Second Soc. Environ. Toxicol. Chem. World Congress Abstracts, Vancouver, B.C.

SYNOPSIS

Start:07/95
End:06/96

Project No.: 04

Title: A Novel Fibrous-Bed Immobilized Cell Bioreactor for Bioremediation of BTEX

Investigators: Yang, Shang-Tian, Huang, Yu-Liang, and Shim, Hojae,
The Ohio State University, Columbus, Ohio

Focus Categories: GW, TS, TRT

Congressional District: Fifteenth

Descriptors: groundwater, biological treatment, biodegradation, Bioremediation, biofiltration, hazardous waste, BTEX, fibrous-bed Bioreactor, immobilized cell

Problem and Research Objectives: Groundwater can become contaminated and undrinkable upon leakage of gasoline from underground storage tanks and pipelines, accidental spills, improper waste disposal practices, and leaching landfills. Contamination is primarily due to the presence of benzene, toluene, ethylbenzene, and xylenes (BTEX), which are more water-soluble, toxic, and mobile than other components of gasoline such as alkanes and polycyclic aromatic hydrocarbons. BTEX compounds are carcinogenic and neurotoxic, and are classified as priority pollutants regulated by the US EPA and are among the target compounds toward EPA's 33-50 program. Benzene is of the most concern because of its association with the development of leukemia in humans.

Many operations in the petrochemical, pharmaceutical, food, and other processing industries involve BTEX as solvents for organic synthesis, equipment cleaning, and other downstream processing purposes. All manufacturing operations which involve VOCs (volatile organic compounds) such as BTEX are coming under increasing regulatory pressure to reduce/eliminate their emissions. In this project, a novel, fibrous-bed, immobilized cell Bioreactor was developed to provide a better technology to remediate the contaminated groundwater and to meet the industry need of an economical solution to their VOC emissions and wastewater discharge problems.

The objective of this research was to develop the aforementioned fibrous-bed Bioreactor as a cost-effective device for biofiltration/biodegradation of VOCs, mainly BTEX, in contaminated groundwater and (waste) streams. To achieve this objective, we investigated the degradation kinetics of BTEX compounds by *Pseudomonas* spp. in the fibrous-bed Bioreactor and did some fundamental studies of fluid and solid (cell) flow and cell immobilization in the porous fibrous matrix in order to optimize and scale-up the reactor.

Methodology: The performance of the Bioreactor was characterized using BTEX as target compounds. The performance of this kind of an immobilized cell reactor has been previously shown to be superior to other fixed-film or suspended-cell systems. The degradation of BTEX was evaluated with a coculture of *Pseudomonas putida* and *P. fluorescens* strains, which was adapted to BTEX in our laboratory. The study focused on the degradation kinetics under various conditions (pH, oxygen tension, medium nutrients). These BTEX compounds including three isomers of xylene were investigated as single compound and in mixtures. BTEX compounds were used in these experiments as sole carbon © and energy sources and as cometabolic parent compounds with glucose as the primary source of C and energy. Interactions of substrates (BTEX), effect of cometabolites (such as glucose and supplemental nutrients), and effect of intermittent operation on the process were studied. Results from the fibrous-bed Bioreactor were also compared to those from other conventional bioreactors. Degradation kinetics was studied by collecting transient data to develop kinetic models for complete mineralization of BTEX. Degradation pathways were also partially determined by identifying intermediate products and by mineralization studies.

Principal Findings and Significance: The fibrous-bed Bioreactor containing an immobilized coculture of *Pseudomonas putida* and *P. fluorescens* strains can tolerate high level (>1,000 mg/L) of benzene and toluene, and gives at least 16-fold higher removal rates for benzene, ethylbenzene, and *ortho*-xylene and 7-fold higher for toluene than those from free (suspended) cell system. Each BTEX compound was efficiently and concurrently removed in the Bioreactor at a retention time of less than 15 hour under liquid-continuous operations, from a synthetic waste stream containing a BTEX mixture. Furthermore, immobilized cells showed no specific preferential removal of BTEX as substrates, whereas free cells showed removal preference in the order of benzene, toluene, ethylbenzene, and xylene; thus, this Bioreactor achieved more efficient removal of BTEX regardless of they are present as single substrate, or as multiple substrates which often exist in natural environments. The superior performances of this immobilized cell Bioreactor are attributed to the three-dimensional structure of the fibrous-bed which provides an environment mimicking the natural environment for cell growth and accumulates a high density of active (viable) cells, compared to those obtained from the free cell system. In this Bioreactor, hydrogen peroxide as an additional oxygen source and glucose as a cosubstrate showed no effect on BTEX removal.

BTEX compounds, selected as model pollutants, possess inhibiting effects on cell growth; therefore, they can represent the characteristics of biodegradation kinetics of a wide range of pollutants in various industrial waste streams. On the other hand, our approach using known coculture rather than unknown mixed culture used by most previously published works gives another advantage of being better for kinetic study and process evaluation. Furthermore, our results show that it is possible to develop an efficient BTEX biodegradation process without providing supplemental nutrients such as cosubstrate and additional oxygen source.

In conclusion, this fibrous-bed Bioreactor shows good performance for BTEX biodegradation, with high removal rates and tolerance, compared to other types of immobilized cell bioreactors previously used for the BTEX removal. Better performance can be achieved if optimized packing configuration and operational parameters were implemented. This immobilized cell system would also be a better device for studying cell kinetics or physiology since it mimics the natural environment with its 3-D structure for cell immobilized.

Publications:

<u>Dissertations</u>

Shim, Hojae, 1996, BTEX Removal by a Bacterial Coculture Immobilized in a Fibrous-Bed Reactor,"Ph. D. Dissertation," Environmental Science Graduate Program, College of Food, Agricultural, and Environmental Sciences, Ohio State University, Columbus, Ohio, 200 pages.

<u>Conference Proceedings</u>

Shim, Hojae, Yu-Liang Huang, and Shang-Tian Yang, 1995, Biodegradation of BTEX by Immobilized Cells in a Novel Fibrous-Bed Bioreactor, "in" Proceedings of Annual American Institute of Chemical Engineers Meeting, American Institute of Chemical Engineers, Miami Beach, Florida, Paper No. 195g.

<u>Manuscript Submitted</u>

Shim, Hojae, Yu-Liang Huang, and Shang-Tian Yang, BTEX Biodegradation by *Pseudomonas putida* and *P.fluorescens* Immobilized in a Fibrous-Bed Bioreactor, Environmental Science and Technology,

Information Transfer Activities

The Water Resources Center has been housed in the Agricultural Engineering Building on The Ohio State University campus. This location has provided daily opportunities to work closely and share ideas with researchers in the College of Agriculture as well as the College of Engineering. It has also provided a close working relationship with the OSU Agricultural Engineering Cooperative Extension Service. A series of tasks were continued or initiated to transfer and disseminate information developed by researchers affiliated with the Water Resources Center to a wide range of State, Federal, County and Municipal agencies; to private sector, to the academic community and to private citizens throughout Ohio.

Water Luncheon Seminar

The Water Resources Center continued to co-sponsor four Water Luncheon Seminar Programs for the water resources community in Central Ohio. These programs, are developed cooperatively with The Ohio Department of Natural Resources (ODNR), the Ohio Environmental Protection Agency (OEPA), the Natural Resources Conservation Service (NRCS), the District Office of the United States Geological Survey (USGS) and the Cooperative Extension Service of The Ohio State University. They continue to attract more than 350 water resources professionals annually from Federal, State, County and Municipal Agencies, the private sector and the academic community. These seminars provide a forum to discuss current state, federal and local water policy issues, problems, programs and research results. In addition to providing speakers for one meeting a year, the Water Resources Center provides the administrative and financial support for the seminars. The Center also provides technical equipment and other support to assist the speakers with their presentations. The programs which were presented during the 1995 series follows.

Water Luncheon Seminar FY 1995

Date	Speaker/Agency	Topic
September 26, 1995	Donna Myers, Supervisor, NAWQA Program Section, USGS	Update: Lake Erie and Lake St. Clair National Water Quality Assessment Study Design & Program
January 9, 1996	Wayne Jones, Hydrogeologist ODNR - Division of Water	Physical & Chemical Analysis of the Mad River and Adjoining Outwash Aquifers, Champaign County, OH
March 12, 1996	Larry Brown, Associate Professor OSU Extension Service OSU Department of Agriculture Engineering	Modeling Drainage Design Parameters to Produce Runoff from Wastewater Irrigated Cropland
May 14, 1996	Gary Overmier, Project Coordinator USDA Natural Resources Conservation Dist.	Port of Toledo/Maumee River Basin Sediment Reduction Project

Other Conferences and Seminars the Water Resources Center Co-Sponsored or Supported in FY 1995

Date	Program	Co-Sponsors
September 19-21, 1995	The Ohio Water Education Program Demonstrations, Presentations, Information - Carol Moody & Jean Morris	Farm Science Review
October 23-25, 1996	Project WET Facilitator Training Workshop in Madison Co. OH	Ohio Water Education Program
November 2, 1996	Floodplain Management & Comprehensive River Basin Planning: Inseparable Activities Operating Independently Gerald E. Galloway, Jr., Chr. Brigadier General (Ret.) White House Interagency Floodplain Management Review Committee	Ohio State University School of Natural Resources Wayne Nichols Memorial Water Resources Center
November 15-16, 1995	Land Use Influences on Water Resources 24th Annual Conference	Water Management Association of Ohio
February 15-16, 1996	Project WET and the Ohio Water Education Program - Carol Moody & Jean Morris	Science Education Council of Ohio Conference
March 3, 1996	Project WET and the Ohio Water Education program - Carol Moody & Jean Morris	Project DISCOVERY
March 6, 1996	Water Education Information Workshop - The Ohio Water Education Program - Carol Moody & Jean Morris	City of Columbus - Division of Water - AWWA - WMAO - OWEA - SWCD - OSU Extension - OTCO - ODNR
March 12-14, 1996	Project WET Facilitator Training Workshop - Ashland Co.	The Ohio Water Education Program
March 18, 1996	Cincinnati - Water Festival Demonstrations/Information/ Presentations	The Ohio Water Education Program
May 16, 1996	Geographic Information Systems Applications for Water Resources, Data, New Applications & Projects Conference	Water Management Association of Ohio
May 4, 1996	Environmental Education Council of Ohio Conference	The Ohio Water Education Program
May 11, 1996	Greenways Conference	The Ohio Water Education Program and Franklin Soil & Water Conservation District

Information Dissemination Activities

The Center continued meeting with the leading water resources officials in the state for the purposes of sharing information on current water management and policy issues; seeking continued support for our water research program and disseminating the information and technology developed through this program and others at the universities throughout the state and region.

The Center, continued publishing its newsletter WATER which focuses on Ohio's water research, technology, issues, legislation in process, education and Center activities. This publication has a wide circulation that includes public officials, water managers throughout Ohio, university researchers in Ohio and throughout the nation, as well as the general public. It has been well received. The editor is Mrs. Carol Moody.

Water Management Association of Ohio (WMAO)

The Water Resources Center continued to be the administrative office for the Water Management Association of Ohio (WMAO). This is the seventh year the Center has provided service to this organization which provides continuous interaction with Ohio's leaders in water resources. This not-for-profit, 250 member, state-wide organization promotes and supports the development, conservation, control, protection and utilization of the water resources of Ohio for all beneficial purposes. It is the only Ohio organization that is solely concerned with managing Ohio's water. The WRC provides staff support, office space and equipment to WMAO as a portion of the information transfer program.

Ohio Water Education Project (OWEP)

The Ohio Water Education Program (OWEP) began in Ohio in the Fall of 1992 with the Ohio Department of Natural Resources and the Water Resources Center. A Memorandum of Understanding supporting this project has been signed by the Water Management Association of Ohio/Water Resources Foundation of Ohio, the Ohio Department of Natural Resources, the Ohio Environmental Protection Agency and the Water Resources Center. There are two functions to this program. The first provides a database of water education materials and projects available/on-going in Ohio; a listing of materials and supplies available for the classroom; and lists of people statewide interested in working with teachers to promote water resources education. This information will be completed and accessible through the World Wide Web in 1996 with educational programming of Ohio School NET and Ohio NET. The second segment of this project is sponsoring the Project WET (Water Education for Teachers). This is a national program for students in grades K-12 for interdisciplinary water resources educationthat is hands-on, inquiry based, interactive learning and meets state curriculum standards. Ohio teachers have indicated tremendous interest in this information and the classroom materials. More than 120 teachers attended workshops to test the materials with 89 completing and are turning the materials to the national office in Montana. Ohio had the most field testers on these materials in the nation.

In the Spring of 1995 the Water Resources Center sponsored two facilitator training seminars for 140 individuals this past year. In the Fall of 1995 and the Spring of 1996 the Water Resources Center sponsored two more workshops, with a total of 260 Facilitators train in Ohio. The demographics of the Facilitators include traditional and non-traditional educators, those in public and private schools, people that teach from pre-school through college; urban, rural and suburban districts , people from local, state and federal governments, and profit and non-profit organizations. Each Facilitator agrees to teach a minimum of a group of ten.

During its first fiscal year of operation from July 1, 1995 through June 30, 1996 there were 96 workshops held in Ohio in which 1,768 teachers were trained to use Project WET materials. It is estimated that each teacher reaches 25 classroom students annually - or that 44,200 students were reached in Ohio during the program's first year in full operation. In addition to providing the administrative assistance for the workshops, the Center staff attended 8 promotional activities for OWEP in the year and gave both formal and informal types of presentations and demonstrations.

The Center also provided all the supplies, interactive models - such as ground water model, EnviroScape® and interactive watershed computer simulator, teacher hand-outs, and 1,600 Project WET books. This project is housed at the Water Resources Center where office space, telephone and fax facilities have been donated in addition to substantial administrative support and services to this program.

The National Project WET Leadership Guidebooks are using many Ohio created materials for their training and reporting materials. The State Coordinator for Project WET also collaborated on "Project Ohio Outdoor Access" a program to adapt Project WET for physically challenged children.

The Department of Energy Project

This is a collaborative, pilot project with seven water resources research institutes nationally. The Ohio Water Resources Center and the Ohio Technology Transfer Center are the lead agencies in this pilot project. Ohio's role has been the development and production of databases for all technologies used that could be adapted or applied to remediation of hazardous and nuclear waste sites, such as the Fernald plant in southwestern Ohio. A SUN work station is operational and the databases that have been developed are on Internet/Gopher protocols. Other people will test the various remediation technologies, and provide educational programs on their progress and they will produce documentation on their findings.

Cooperative Arrangements

Program Development

A call for pre-proposals for the Fiscal Year 1995 State Water Resources Research Program was mailed to reach administrators and qualified faculty investigators at more than 40 private and public colleges and universities throughout Ohio in mid-November, 1993
. This announcement contained the research priorities identified for the major water problems in the Great Lakes, Upper Mississippi and Ohio River Basins by the Water Resources Research Institutes in the Region.

The announcement also required interested researchers to request a copy of the Preliminary Proposal Application Form which was to be completed and returned to the Water Resources Center in late January, 1994.

Pre-Proposals/Federal Guidelines

Preliminary Proposal Application Forms were requested by and sent to twenty-three investigators and research administrators at ten colleges and universities in Ohio. Central State University, an Historically Black University, was one of these colleges, but they did not request any pre-proposal information. In addition to the application form, a list of the federal guidelines for the Program was also enclosed.

Evaluation/Selection Procedures

Ten pre-proposals from six universities and colleges throughout the state were submitted for evaluation and consideration. These pre-proposals were subjected to a review by all of the members of the Water Resources Center's Advisory Committee. In addition, these pre-proposals were distributed to the various divisions within the principal state and federal water-related agencies in the State by the representatives of these agencies who serve on the Advisory Committee, requesting that the divisions review the proposals. The four agencies included in this evaluation were the Ohio Department of Natural Resources, the Ohio Environmental Protection Agency, the District Office of the United States Geological Survey and the Agricultural Research Service in the United States Department of Agriculture.

The results of these reviews were presented at a meeting of the Advisory Committee where this panel selected five of the pre-proposals and instructed the Center's Director to request fully developed proposals from the investigators for the Committee's further consideration.

The five pre-proposals were developed more fully and were re-submitted for consideration. The proposals were subjected to a technical review by at least three qualified evaluators selected by individual members of the Water Resources Center's Advisory Committee. Many of these evaluators were from state and federal agencies.

The results of these reviews were presented at a meeting of the Advisory Committee and this panel ranked the leading proposals in the order they felt would best meet the needs and objectives of the Water Resources Center's programs. The Advisory Committee then instructed the Center's Director to incorporate as many of these projects as Federal funds would permit into the FY 1995 Program, and to develop a project for information transfer for the Center. There was enough Federal monies to support three projects.

The membership of the Water Resources Center's Advisory Committee, which includes representatives from four colleges and ten departments of The Ohio State University and representatives of the principal state and federal water related agencies is included in this report.

Regional Cooperative Initiatives

The projects selected for the FY 1995 Program were compared with the programs of the other Water Resources Research Institutes in the Great Lakes, Upper Mississippi and Ohio River Basin to ensure that there was no duplication of efforts in the Region's research programs.

The Ohio State University agreed to continue as a Charter Member of the Ohio River Basin Research and Education Consortium, and the Director of the Water Resources Center has continued to serve as one of the University's three representatives to the Consortium.

In July 1995 a new Director, Earl Whitlatch, was appointed by the Chair of the Department of Civil and Environmental Engineering and Geodetic Sciences. As Director he joined the National Institute for Water Resources (NIWR), Universities Council on Water Resources (UCOWR), the Water Management Association of Ohio (WMAO), and the Ohio River Basin Consortium for Research and Education (ORBCRE).

Program Management

At least once each quarter, the Director contacts the Principal Investigators on each research and information transfer project to discuss progress made during the quarter and to discuss the next quarters plan of activities. At this same meeting budget details are reviewed and discussed, and necessary operating and reporting procedures to the Water Resources Center and to The Ohio State University Research Foundation's business office are described. Progress Reports or Completion Reports are prepared for each project by the Principal Investigators and for the Program Director to prepare the Program Final Report.

All of the investigators are urged to publish the results of their findings in the technical literature of their major disciplines and in other journals that are appropriate to the topic of their research. They are also encouraged and invited to present their findings at the Water Luncheon Seminar or other local meetings as part of the information transfer program.

The manuscripts that constitute the project completion reports are first reviewed by the Director of the Water Resources Center. As needed the Director seeks the advice and council of appropriate state, federal and university scientists for methods of enhancing the value of the technical completion reports to the water-related community in the state and in the region.

Training Accomplishments

The following tabulation shows, by fields of study and training levels indicated, the numbers of individuals participating in projects that were financed in part with this grant.

Training Category **Training Level**

Discipline	**Bachelor's Degree**	**Master's Degree**	**Ph.D. Degree**	**Post Ph.D.**	**Total**
College of Biological Sciences Environmental Toxicology			3		3
College of Agriculture					
Food, Agriculture and Environmental Sciences			1		1
Geology Department		1	_		1
	Totals	**1**	**4**		**5**